Appendix AD

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HOW, AND WHY, IS THE GOSHAWK (*ACCIPITER GENTILIS*) AFFECTED BY MODERN FOREST MANAGEMENT IN FENNOSCANDIA?

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ABSTRACT.—The Northern Goshawk (*Accipiter gentilis*) is a common raptor in the boreal forest of Fennoscandia (Norway, Sweden and Finland), with a present breeding density of about 3 pr/100 km² of forest area. Several independent studies show that goshawk populations in Fennoscandia have declined by 50–60% from the 1950s to the 1980s. This decline coincides in time with an intensification of forest management, which has changed the forest landscape. Among other effects, forests are more fragmented and the proportion of old forest is decreasing. Neither pesticide use nor persecution can explain the goshawk decline. However, changes in habitat and prey populations are both important factors that are affected by forestry. Goshawks need only a small patch of suitable habitat for nesting, but for their foraging home ranges cover 2000–6000 ha, and in boreal forest areas they prefer large patches of mature forest. I suggest that changes in the boreal forest landscape have resulted in a deterioration of goshawk hunting ranges, making it more difficult for them to secure adequate food for breeding. This factor is more important than a shortage of suitable nest sites. Declining prey densities (e.g., grouse) may be associated with forestry and is also an important factor that may affect goshawk numbers.

KEY WORDS: Accipiter gentilis; *Northern Goshawk; forest management; home range; breeding; habitat selection; Fennoscandia; Sweden; Norway; Finland.*

¿Como, y Porque, esta el *Accipiter gentilis* afectado por la administración forestal moderna en Fennoscandia?

RESUMEN.—El *Accipiter gentilis* norteño es un rapaz común en el bosque boreal de Fennoscandia (Noruega, Suecia y Finlandia) con una densidad de cría presente como 3 pr/100 km² de área bosque, varios estudios independientes enseñan poblaciones de *Accipiter gentilis* en Fennoscandia aun reducido por uno 50–60% de los 1950s a los 1980s. Está reducción coincide con el tiempo de intensificación de *administración* de bosque, que ha cambiado el paisaje del bosque. Entre otros efectos, bosques están mas fragmentados y la proporción de bosques viejos se esta reduciendo. Ni uso de pesticida ni persecución puede explicar reducción del *Accipiter gentilis*. Sin embargo, cambios en el hábitat y poblaciones de cazar son las dos importantes factores que son afectados por forestales. *Accipiter gentilis* necesitan no mas una parcela chiquita de hábitat conveniente para hacer nidos, pero sus forrajes naturales cubren 2000–6000 ha, y en áreas de bosque boreal ellos prefieren parcela grandes de bosque maduro. Yo, propongo que cambios en el paisaje de bosques boreal han resultado en un empeoramiento en campos de cazar del *Accipiter gentilis*, haciendo mas difícil para ellos a proveer suficiente comida para cría. Este factor es mas importante que una falta de nidos conveniente. La reducción de densidad de cazados, (por ejemplo, urogullo) puede ser asociada con forestales y es también un factor importante que puede afectar la cantidad de *Accipiter gentilis*.

[Traducción de Raúl De La Garza, Jr.]

The forests of Fennoscandia (Norway, Sweden, and Finland) have been used by man for a very long period of time. However, in the 1950s, a major change occurred in forest-management practices, including intensified methods based on clear-cutting, replanting and thinning. This practice gradually replaced the traditional way of harvesting forest by selective cutting. In Sweden, 58% of the land area is productive forest which is very intensivel managed. About 40% of this area has been clea cut since 1950 and is now covered by forest estal lished according to modern methods (Anonymou 1989).

As a result of this intensive management, the b real forest landscape of Fennoscandia is now highly fragmented patchwork of clear-cuts and fo

Table 1. Population studies showing goshawk density changes in boreal forests of Fennoscandia.

Study Area	Period	Change in Breeding Pairs	Density Change (pr/100 km²)
Central Norway[a]	1964–93	8 → 0	3.7 → 0
Southern Norway[b]	1950–84	13 → 5	7.2 → 2.7
Southern Norway[c]	1950–85	35 → 20	9 → 5
Southern Norway[c]	1985–88	20 → 26	5 → 4
North-central Sweden[d]	1950–76	12 → 5	2.4 → 1
Central Sweden[e]	1950–70	10 → 5	2 → 1
Central Sweden[f]	1960–80	35 → 15	35 → 15
Southern Finland[g]	1974–81	25 → 10	5 → 2
Southern Finland[h]	1977–84	16 → 10	3.3 → 3.3

[a] Tømmeraas 1993.
[b] Hansen 1985, Frydenlund Steen 1989.
[c] Selås unpubl. data.
[d] Carellus (1978).
[e] Bylin (1975).
[f] Lind (in Nilsson, 1981).
[g] Wikman and Lindén (1981).
[h] Forsman and Ehrnsten (1985).

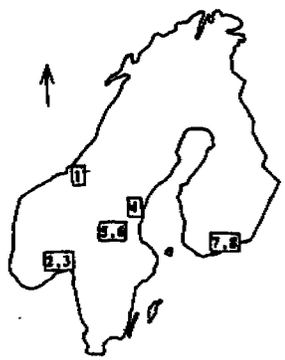

Figure 1. Map showing the location of goshawk population studies cited in the text. 1. Tømmeraas (1993), 2. Hansen (1985), Frydenlund Steen (1989), 3. Selås (pers. comm.), 4. Carellus (1978), 5. Bylin (1975), 6. Lind (in Nilsson 1981), 7. Wikman and Lindén (1981) and 8. Forsman and Ehrnsten (1985).

est stands in different successional stages. Less than 5% of the Swedish forests are primeval, as compared to 22% and 60% of the forests in the U.S. and Canada, respectively (Olsson 1992).

The Northern Goshawk (*Accipiter gentilis*) occurs in forested areas throughout the Holarctic region (Brown and Amadon 1968), and is one of the more numerous birds of prey in Fennoscandia. The object of this paper is to review available information about goshawk population status and trends in the Fennoscandian countries and to discuss possible effects of modern forest management on those trends.

Population Status

In Norway, the goshawk population was estimated to be 2700 breeding pairs (Bergo 1992). This is equivalent to 0.8 breeding pr/100 km² of land area and 3.1 pr/100 km² of forest area.

The Swedish goshawk population was estimated at 10 000 breeding pairs by Svensson (1979), based on a nationwide bird censusing program. However, Nilsson (1981) suggested that there were only 6000 breeding pairs after analyzing a number of different local studies. Marcström and Kenward (1981), based on capture-recapture estimate of ringed (banded) birds, calculated that the number of goshawk pairs older than two yr was between 3500 and 13 600. I judge the two latter estimates to be the most reliable and conclude that the Swedish goshawk population is about 7000 breeding pairs, which is equivalent to a breeding density of 1.9 pr/100 km² of land area and 2.9 pr/100 km² of forest area.

The goshawk population in Finland was estimated at about 8000 breeding pairs by Saurola (1985a), implying a breeding density of 2.0 pr/100 km² of land area and 3.0 pr/100 km² of forest area.

Thus, although the density per land area differs between the Fennoscandian countries, the density per forest area is virtually the same, about 3 breeding pr/100 km² of forest.

Population Trends

The best way to study long-term population changes in raptors is to monitor a breeding population of a given area for a long period of time. By examining trends in individual populations, we should be able to make conclusions regarding trends over larger areas. In Fennoscandia, a number of such local, long-term goshawk population studies have been reported, and they are summarized in Table 1. The locations of the studies are shown in Fig. 1. A paired *t*-test between early and late years show a statistically significant decline ($t = 3.474$, df = 8, $P = 0.0084$).

Thus, it is well documented from a number of different, independent studies in all three Fennoscandian countries that goshawk populations have decreased from around 1950 to around 1980. In most studies, the decrease has been 50–60%. After that period, the pattern is less clear since most studies have not continued. However, the nationwide raptor monitoring scheme in Finland indicates stable populations after 1982, when the program started (Huupala et al. 1994), and Selås (pers. comm.) reports a temporary, slight increase in one area of Norway.

Why Has the Goshawk Declined?

To determine the reasons for such a dramatic decline, we must look at all possible environmental factors, not only forest management. The factors most often associated with declining raptor populations are pesticides, persecution, declining prey populations and habitat degradation or loss (Newton 1979).

Pesticides. Most adult goshawks in the boreal forests of Fennoscandia are not migratory and remain in or close to the boreal forest throughout the year. Further, their most important prey species are also sedentary. Thus, they do not directly pick up contaminants from other regions, probably making them less vulnerable than other raptor species to pesticide contamination. However, juveniles and some adult females move south and winter in farmland areas (Widén 1985), where there is more prey, but also generally more pesticide use than in forested habitats.

Mercury. In Sweden, alkyl-mercury was used for seed dressing in agriculture from the 1940s until 1966, when it was prohibited. This use caused widespread contamination of the terrestrial fauna, and as a result many terrestrial bird species were seriously affected (Berg et al. 1966, Borg et al. 1969, Jensen et al. 1972, Westermark et al. 1975, Johnels et al. 1979). Increased levels of mercury were found in breeding female goshawks' feathers in the period 1940–65, but decreased to background levels rapidly after alkyl-mercury was banned in 1966 (Johnels et al. 1979).

Organochlorines. A common way of assessing the impact of organochlorines on raptor populations is by measuring the eggshell thickness. Newton (1979) concluded that whenever a population showed more than 18–18% shell-thinning over several years, it declined. Nygård (1991) reported a 6.6% decrease in eggshell thickness in eggs from goshawks in Norway after 1947, a result that suggests organochlorines have not been an important factor in their population decline.

Thus, although pesticide use has been reported as the cause of declines in goshawk populations in other parts of Europe (Bijlsma 1991), I conclude that there is no evidence that this has been the case in the boreal forest region. When the use of persistent pesticides stopped in the early 1970s, positive goshawk population trends were reported throughout Europe (Bijlsma 1991). In the boreal forest region, this has not occurred and goshawks did not recover when the pesticide situation improved. In fact, several population studies show that goshawks declined even after mercury levels dropped. This can be compared to the Sparrowhawk (*Accipiter nisus*), which decreased drastically in Sweden from the 1950s, but recovered markedly when organochlorines were prohibited in the 1970s (Wallin 1984).

Persecution. Goshawks have always been persecuted in Europe, especially in farmland areas by hunters wanting to protect small game species from predation. In Fennoscandia, this has mainly affected wintering juvenile goshawks. Locally, persecution also affected adult breeding birds since some hunters specialized in finding and destroying breeding goshawks. However, during the period of goshawk decline between 1950–80, legal protection has improved and there has been a gradual changing opinion favoring raptors, leading to reduced pressure of persecution. Accordingly, Saurola (1985b) reports a 50% decrease in goshawk persecution between 1960–80. Thus, persecution is not likely to be the major reason for goshawk decline in Fennoscandia.

Prey Populations. The goshawk feeds on a wide variety of prey species, but in the boreal forests of Fennoscandia different grouse species are the most important prey (Höglund 1964, Sulkava 1964, Tornberg and Sulkava 1990), although in winter squirrels (*Sciurus vulgaris*) may also be a major prey item (Widén 1987). It is well documented that goshawks respond numerically and functionally to short-term fluctuations in grouse populations (Lindén and Wikman 1980, 1983) and they are likely to respond also to long-term population changes.

Selås (pers. comm.) suggested that the goshawk decline was caused by a decline in forest grouse, due to a long-term increase in the number of generalist predators such as red foxes *Vulpes vulpes* (Storaas and Wegge 1985, Storaas 1993). The increase in goshawk numbers from 1985 in his area

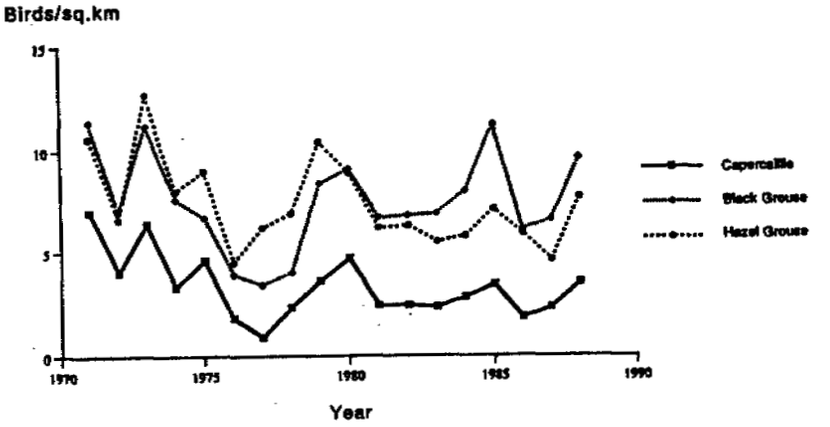

Figure 2. Population trends in forest grouse: Capercaillie (*Tetrao urogallus*), Black Grouse (*Tetrao tetrix*) and Hazel Grouse (*Bonasa bonasia*) in southern Finland (Finnish Game and Fisheries Res. Inst. unpubl. data).

was explained as a temporary reversal of this process, when the red fox drastically decreased due to sarcoptic mange, resulting in an increase in grouse numbers. However, the red fox is now recovering and there will probably not be any long-term effect on prey numbers. Thus, Selås explains the goshawk population changes as long-term numerical responses to changing prey populations.

Wikman and Lindén (1981) found that the goshawk decline coincided with a general decline in grouse numbers in the same area, but concluded that the rather moderate grouse fluctuations could not explain the 60% decline in the goshawk population. Grouse populations were very low in 1976–77 when the goshawk decline started. Although grouse numbers increased for a number of years after 1977, goshawks failed to respond numerically and still remain at a low population level. More recent grouse data (Finnish Game and Fisheries Research Institute unpubl. data) show a continuing downward trend in numbers of Capercaillie (*Tetrao urogallus*), Black Grouse (*Tetrao tetrix*) and Willow Grouse (*Bonasa bonasia*) in Finland (Fig. 2).

Thus, there is some indication that decline in prey populations, mainly grouse, is a factor involved in the long-term decline of Fennoscandian goshawk populations. Unfortunately, for most of the studies reporting goshawk decline, there are no good corresponding data on grouse populations, so it is unclear how general this explanation is. Further, the fact that the goshawks in southern Finland failed to respond to increasing grouse populations in the late 1970s and the early 1980s, indicates that the relationship between grouse and goshawks is not always a simple numerical response.

Habitat Degradation or Loss. Goshawk habitat can mean different things. Quite often it refers to nesting habitat (e.g., the site where the bird builds its nest and breeds). Less often it refers to the rest of the bird's living space (e.g., the home range that is used to find the food necessary for survival and raising of young). Here, I will cover both aspects, since both of them are important for goshawk survival.

Nesting habitat. Several reports (Carelius 1978, Forsman and Ehrnsten 1985, Hansen 1985, Prydenlund Steen 1989, Tømmeraas 1993) have indicated that goshawk population declines were mainly or partially due to the loss of nest sites during modern forest management.

The breeding habitat of Northern Goshawks has been described by several authors (Dietzen 1978, Reynolds 1983, Reynolds and Meslow 1984, Link 1986), and generally it is found that goshawks do not select nest sites randomly. Since nest sites are relatively easy to find and describe, there is a tendency to emphasize the importance of that part of the bird's environment, as compared to the much larger home range. Goshawks need only a small patch of suitable habitat for nesting and successful goshawk breedings have been reported in forest patches as small as 0.4 ha (Lindell 1984). One goshawk nest was recorded in an isolated willow tree (*Salix alaxensis*) in Alaska, 145 km north of the tree line on the tundra (Swem 1992).

The reported habitat requirements may not be specific, observed relationships may not be causal and, if they are, they may not represent major restraints (Kenward and Widén 1989). Although lack of nest sites may become a problem on a local scale, it seems unlikely that it should become limiting on a larger scale for goshawk populations in boreal forests, even in strongly impacted systems. For example, the study area in central Sweden where Widén (1989) studied goshawk hunting habitats was an area with very intensive forest management, yet the proportion of mature forest suitable for nesting goshawks was about 24%.

I conclude that nesting habitat availability is not likely to be a major factor behind the recorded decline in goshawk numbers.

Hunting habitat. Goshawks move over large areas when hunting, and in Sweden home range sizes are between 2000–6000 ha (Kenward 1982, Widén 1989). Important clues regarding hunting habitat requirements might be found by taking a closer look at how the goshawk uses this landscape, especially where and how it hunts.

Widén (1989) studied goshawk hunting habitat with radiotelemetry in continuous coniferous forest in the boreal forest region of Sweden (Sjörs 1965); at Grimsö Wildlife Research Station. Of the area, 74% was conifer-dominated forests. Bogs and fens comprised 18% of the area and only 3% was farmland. Of the six different habitat classes, goshawks strongly preferred mature forest. Some hawks were monitored more intensively in order to record their predation, and results showed that most kills were made in mature forest, strongly indicating that this was the most important hunting habitat. It was also clear that goshawks preferred large patches of mature forest, although the preference for large patches was evident in the mature forest only. It was also in the large patches that most kills were made.

The goshawk hunts by making short flights between perches, where it stays for longer periods and from which nearly all attacks are made (Kenward 1982, Widén 1984). With such a hunting technique, it is obvious that hunting success depends not only on prey density, but also on different habitat features that determine its ability to hunt. This may be a major factor behind their preference for hunting in mature forest. It is important for the hawk to reach perches undetected by prey and to remain undetected. At the same time, habitat must be open enough for the goshawk to maneuver and attack. The mature forest is the best compromise; prey in more open or denser habitat is less accessible. For example, goshawks avoided young forest, despite the fact that this habitat was preferred by one important prey species, the Black Grouse (Kolstad et al. 1985).

Due to forestry, the proportion of old, mature forest in Sweden has decreased (Svensson 1980) and the forest is being fragmented into smaller patches. Obviously, both trends may negatively affect goshawks in boreal Fennoscandia.

Kenward (1982) studied goshawk habitat utilization in three areas with mixed farmland/woodland in central Sweden, containing 41–61% woodland. In all areas, he found preference for forest as compared to farmland, although he did not separate successional forest stages. He also found a preference for forest edge. The forest patches he studied were surrounded by farmland where prey occurred, predominantly Ring-necked Pheasants (*Phasianus colchicus*) and European hares (*Lepus europaeus*). Goshawks used the forest edge as cover where they perched and from where attacks were launched.

In the Widén (1989) study area, the forest patches were mainly surrounded by forests in other successional stages (e.g., younger than the preferred mature forest). These younger stages offered no good hunting habitats for the hawks and thus the edges were not preferred.

Discussion

Effects of Forest Management. Available data show that Fennoscandian goshawk populations have declined by 50–60% from the 1950s to the 1980s, and I have concluded that neither pesticides nor persecution can explain this decline, but that changes in prey populations and habitats are important factors. Further, it is striking that the decline coincided in time with forest-management intensification. Thus, we are left with the conclusion that forest management, acting in different ways, is a prime factor behind the goshawk decline. I suggest that large-scale changes in the boreal forest landscape, caused by modern forest management, has resulted in a deterioration of goshawk hunting

range quality, and that this, although difficult to measure, is more important than nest-site availability. When discussing habitat suitability, it is important to include prey accessibility and density in addition to nest-site availability. The goshawk requires prey that it is able to catch. To discover important hunting habitat requirements, one needs to know where raptors hunt and their hunting success in each place (Kenward and Widén 1989).

In Denmark, which is south of the boreal forest, the population trend seems to have been different. Here, the goshawk has increased from the 1960s until the beginning of the 1980s (Jørgensen 1989). This was explained as a result of decreased pressure from persecution and pesticides.

My conclusion that hunting habitats are more crucial than nesting habitats for goshawks in the modern forest landscape does not indicate that availability of good nesting habitat can be completely rejected as a possible limiting factor for goshawk populations. Since goshawks are territorial, with a regular spacing of nests (Widén 1985), they cannot breed close together, and therefore it is important how the patches of good nesting habitat are spaced.

Further, there must be more suitable habitat patches than are currently needed. New individuals recruited into the population must be able to find unoccupied sites. In order for the whole population to survive, sites that are temporarily unoccupied must be available for colonization by new breeders. A site that has become temporarily unoccupied is a potential resource for new breeders, which are recruited into the population. If unoccupied sites are destroyed because there are no longer any hawks there, we lose that possibility. A raptor population may go extinct because of a lack of nest sites, even if we never destroy a single occupied nest site, but destroy those that are temporarily unoccupied.

Declining prey populations can be an important factor, but the relationship between prey decline and forestry needs to be explained. Selås (pers. comm.) explains grouse number declines as an effect of increasing numbers of red fox, but does not explain why foxes have become more common. Forsman and Ehrnsten (1985) argue that the goshawk decline is due to modern forestry, affecting the goshawk in two different ways. Birds of optimal prey size (e.g., grouse) are becoming rarer and are being replaced with smaller birds. Second, good nesting habitat (e.g., mature forests) is becoming rarer. Wikman and Lindén (1981) argue that lack of nesting habitat is not a problem, but that habitat destruction may act indirectly by depleting habitat for prey animals.

A general discussion about grouse populations in Fennoscandia is beyond the scope of this paper, but considering the effects that forestry has had on the forest landscape, it would be surprising if grouse have not been affected.

The goshawk problem in boreal forests cannot be solved by creating protected areas; they need areas too large to be effectively protected that way. We must concentrate on determining what is important for goshawks and use that knowledge to direct forestry practices that establish adequate protection.

Recommendations. First, when mature forest is fragmented by clear-cutting, the fragments should be as large as possible. It is generally better to make one large clear-cut than several small ones. Second, nest sites must be protected, even if they are unoccupied. A surplus of well-spaced patches of good nesting habitat is needed. Third, there must be enough forest with old-forest qualities in the landscape. Research is needed to determine how much is enough. Fourth, we need more research on the goshawk's hunting technique and hunting success in different habitats.

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